Setting the scene for a successful fish screen: behaviour and other considerations

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Plan of talk

- Background – Back to Basics
- Physical, Performance, and Behavioural Screens
- Bias in understanding
- Fish behaviour in response to hydrodynamics
- Recommendations
Main driver for our interest in screens – Legislation?

“require the operators of fish passes, sluices, by-washes and screens to maintain these facilities to ensure the safe passage of salmon past dams and off-takes.”

Salmon (Fish Passes and Screens) (Scotland) Regulations 1994

• The Conservation (Natural Habitats and Conservation) Regulations 1994.
• The Environment Act 1995
• Water Framework Directive
• The Eels (England and Wales) Regulations 2009
Fisheries Engineering

Block access and divert
- e.g. Screening irrigation ditches
- Bypass structures

Enable access
- e.g. Adult fish ladders at dams
- Fish friendly culverts under roads
Rotary Drum Screen - Idaho
Screening water intakes at power stations
Smolt Bypass

Screening device
Types of barrier (screen)

- Physical (positive)
- Performance
- Behavioural
1. Physical barriers

Extended length bar screens
Lower Granite Dam, Columbia River USA.

Submerged traveling screens
McNary Dam.
Debris build up and screen maintenance
Effectiveness of screens can be spatially and temporally variable.
1. **Entrainment:**
   When a fish passes through the screen into the diversion and passes into a canal or turbine. Consumptive versus non-consumptive water use (when to screen and when not to screen!).

2. **Impingement:**
   Where a fish comes in contact with a screen, a trashrack, or debris at the intake. This causes physical damage and if prolonged, repeated, or occurs at high velocities will cause direct mortality.

3. **Delay:**
   Screen prevents migration or induces avoidance. Increase risk of stress, disease, energy loss, and predation impacting probability of survival.
2. Performance barriers

Performance varies with size of the fish

EFFECT OF FISH SIZE ON CRITICAL SWIMMING VELOCITY OF SALMONID FRY AT 7°C (SMITH AND CARPENTER, 1987)
Intentional performance barrier

Sea Lamprey control on the Great lakes
Mechanical control of lamprey

Lamprey trap

Low head velocity barriers

Adjustable crest barrier
3. Behavioural barriers

- Light (acts as attractant and repellant)
- Acoustic barriers
- Bubble screens
- Combination e.g. Acoustic bubble screens
- Electric barriers
- Overhead cover
- Rapid accelerations of flow
Light as an attractant or repellent

The behavioral response of fish to light varies with respect to:
- Taxa
- Life-stages
- Physiological state
- Water clarity
- Flow conditions

Intense illumination has shown to be a deterrent for clupeids, lake whitefish, striped bass, rainbow trout, and salmonids.
Floodlights used to attract juvenile Chinook salmon to Spillways

Food Shortage – WW II

Lights used to deflect eels into mill leats and traps during FBA research.
Strobe lighting – Ballard Locks, Seattle USA.

The main intake to the locks has been surrounded with strobe lights designed to scare ocean-bound smolts away from the filling culverts.
Infrasound
Infrasound induces an avoidance response in migrating European eels

River Imsa, Norway  Sand et al. 2000
A novel smolt counting system, developed by CEH, incorporating acoustic bubble screens (Fish Guidance Systems Ltd) to divert fish through counters (Welton et al., 2002).
Some considerations for behavioural barriers:

1. Benefit: can cost considerably less than physical barriers.
2. Less likelihood of mechanical damage
   e.g. impingement - good for small fish.
3. Guidance efficiencies are generally lower than for physical barriers.
   (i) large response variation between individual fish of the same size and species.
   (ii) Habituation after repeated exposure.
   (iii) limited application when strong, or accelerating water velocity fields, result in the fish being unable to respond to a stimulus, even if it attempts to do so.
Bias in understanding

1. Focus towards salmonids;

2. As a result, focus towards Northern Hemisphere;

3. Criteria based predominantly on understanding swimming capability, less so on behaviour;

4. Focus on mechanical screening devices.
Variation between species:

Fish guidance efficiency at the Columbia River Dams

The efficiency with which juveniles are guided away from the turbines to bypass systems:

Steelhead: 80-90%
Spring/summer Chinook: 60-70%
Fall Chinook: 30%

US Corp of Engineers
Pacific Salmon Coordination Center
Fish protection criteria for fish screens (from NMFS 1995)

1. A uniform flow distribution over the screen surface to minimize localized areas of high approach velocity ("hot spots").
2. Approach velocities less than or equal to 12.2 cm/s (0.4 ft/s).
3. Sweep velocities that are greater than approach velocities.
4. A minimum bypass entrance flow velocity greater than the maximum true flow velocity upstream of the bypass entrance.
5. A gradual and efficient acceleration of flow from the upstream end of the site into the bypass entrance to minimize delay of emigrating salmonids.
6. Screen submergence between 65-85% for drum screen sites.
7. Water depth at bypass outfall >30.5 cm.
Large channel swimming performance tests
Role of Turbulent Eddies in Fish Swimming Ability

Vortices = negative impact on swimming performance

But, depends on dimensions of vortices relative to body length of fish.
Experiment Conclusions

- Eddies do affect the critical swimming speed of creek chub
  - Cylinder orientation
  - Diameter
  - Circulation
Karman gaiting – fish utilise energy from vortices to enhance swimming Performance – Professor Jimmy Liao et al.
Fish behaviour in front of screens

- See “Screening for intake and outfalls: a best practice guide”
  - Rainey 1985
  - Pavlov 1989
  - Turnpenny et al. 1998

Beware of interspecific variability impacting the efficiency of screens when considered for multispecies protection (see Russon et al. 2010)
Vector plot downstream of the boom showing the mean velocity vector ranging from minimum 0.14 m/s (dark blue) – maximum of 1.12 m/s (dark red). Direction was determined based on the direction of the largest velocity component. Scale: 1:150.
Downstream passage (American eel) – Hydroacoustic Telemetry

From Brown et al. 2009
Need for monitoring screen efficiency
Recommendations

- More research needed to address bias in understanding if we are to design effective multispecies screening systems
  e.g. what do we do about elvers?

- Behaviour, in addition to swimming capability, should be considered in the design of screens.

- Need to better monitor effectiveness of screening systems using both laboratory and field techniques.